REMARKS

Claims 1-3, 16, 20, 26-28, 53-54 and 57-58 are amended herein. Claims 55-56 are canceled. Claims 1-16, 20, 22-54 and 57-58 are pending.

Response to Rejection Under 35 USC §102

Claims 1-18, 20-56 and 58 were rejected under 35 U.S.C. 102(e) as being anticipated by Biswas et al (US 7,197,074) ("Biswas1"). Applicants respectfully traverse.

As amended, claim 1 now recites:

> A computer implemented method of determining a motion vector for encoding a block of a predicted frame with respect to a reference frame, the method comprising:
> establishing a size for phase correlation blocks based on maximum allowable magnitude of the motion vector, the maximum allowable magnitude being based on an encoding parameter for controlling image quality;
> identifying a number of highest phase correlation peaks between a phase correlation block of the predicted frame and a corresponding phase correlation block of the reference frame, the phase correlation block of the predicted frame including the block, wherein the number of identified phase correlation peaks increases as the size of the phase correlation block increases;
> determining for each identified phase correlation peak, a motion vector; and
> selecting from the motion vectors, a motion vector that minimizes a distortion measure between the block and a reference block offset from the block by the motion vector.

Claim 27 recites a corresponding method for frame-level motion vector determination, and claims 28 and 53 recite a corresponding circuit apparatus and circuit means, respectively. These features provide methods and apparatuses for selecting a motion vector for encoding a block of a predicted frame in three stages. The selected motion vector for the block to be predicted is the one that minimizes a distortion measure between the blocks of the predicted frame and a reference block.

For purposes of explanation, the claimed approach may be understood as having three stages of selection:

- a first selection stage: establishing a size for phase correlation blocks based on maximum allowable magnitude of the motion vector;
- a second selection stage: identifying a number of highest phase correlation peaks within a current phase correlation block of the size established in the first stage. Each of these peaks is associated with a candidate motion vector from the current phase correlation block to a reference block; and
- a third selection stage: selecting a motion vector, from the identified candidate motion vectors at the second selection stage, that minimizes a distortion measure between the current phase correlation block and a reference block.

These stages enable an encoding system and method to balance the tradeoff between encoding speed and image quality. For example, *establishing a size for phase correlation blocks based on maximum allowable magnitude of the motion vector* beneficially eliminates all candidate motion vectors that fall outside a middle portion of the phase correlation surface because these motion vectors are poor candidates for high quality video compression. *See* Specification at [0024] for a further explanation of one embodiment of this step.

Second, the claimed invention includes identifying a number of highest phase correlation peaks between a phase correlation block of the predicted frame and a corresponding phase correlation block of the reference frame. Each of these peaks is associated with a motion vector (determining for each identified phase correlation peak, a motion vector). This step is beneficial, for example, as it greatly reduces the number of candidate motion vectors to be further evaluated, while still allowing the encoding process to achieve good compression efficiency because these identified candidate motion vectors represent the "most likely" motion vectors for the block being encoded.

Further, this selection stage supports implementation flexibility with good compression efficiency. For example, the claimed method may be implemented to determine a fixed number of highest phase correlation peaks (e.g., claim 10), a variable number of highest phase correlation peaks (claims 1 and 44); determine a number of highest phase correlation peaks as a function of a size of the block (claim 45), or as a function of a variance

of the values of the highest phase correlation peaks (claim 46). See Specification at [0036] for examples. Such flexibility enables the claimed encoding system and method to scale to higher resolution images, such as Standard Definition (720x480 pixels) and High Definition (up to 1920x1080 pixels).

Another example beneficial aspect of the first and second steps described above is that they have low computational complexity. For example, they do not require computationally expensive operations, such as the sum of the mean square error (MSE) of pixel differences, or the sum of the absolute value of the pixel differences (SAD) as used by Biswas1.

Finally, the claimed invention includes selecting from among the identified motion vectors, the motion vector *that minimizes a distortion measure between the block and a reference block offset from the block by the motion vector.* Here, this step beneficially identifies not merely a satisfactory motion vector, but what may be considered as the "best" one of the identified motions vectors (*best* in the sense that it results in minimized distortion in the reconstructed image).

Biswas1 does not disclose the claimed limitations. First, Biswas1 does not disclose *establishing a size for phase correlation blocks based on maximum allowable magnitude of a motion vector* as claimed. Biswas1does not allow for varying the size of the phase correlation blocks <u>based on a maximum allowable magnitude of the motion vector</u>. As a result, in Biswas1 every phase correlation peak is treated as a candidate motion vector. *See* Biswas1 at col.4:50-52. Because of this, each and every candidate motion vector undergoes an elaborate and computationally expensive correlation and validation process (based on MSE and SAD computations). *See* Biswas1 at col.4 and col. 5. Due to the complexity of this scheme, Biswas1's correlation and validation process is terminated as soon as the first candidate

motion vector is found which has less than a "selected limit for error" threshold. See Biswas1 at col.5:62-col.6:5.

For example, Biswas1's phase correlation analysis uses a correlation and validation process to select a list of valid correlation peaks, i.e., candidate motion vectors. *See* Biswas1 at col. 5:2-13 and FIG. 5. In Biswas1, the correlator 120 correlates using a sub-block being processed and a neighborhood of 8 surrounding sub-blocks. The size of the sub-block being processed may be chosen based on recognition of the difficulty of the video being processed. *See* Biswas1 at col. 4:61-65. As such, not only the validated motion vectors corresponding to sub-blocks in the <u>current frame</u> but also motion vectors of the <u>reference frame</u> need to be used for the correlation. *See* Biswas1 at col. 5:14-19 and FIG. 5. For 9 sub-blocks used to perform a correlation there are 9N motion vectors involved, where N is the number of candidate motion vectors from each sub-block. Thus Biswas1 requires significant memory allocation for the 9N vectors, as well as a large number of computations for evaluating all of these vectors.

Furthermore, Biswas1 does not teach selecting a motion vector that minimizes a distortion measure between the blocks of the predict frame and a reference block, as claimed. Instead, in Biswas1, correlation for each candidate motion vector for the sub-block being processed is made by comparison to an error threshold, and the error threshold is measured by, for example, the sum of the mean square error (MSE) of pixel differences, or by the sum of the absolute value of the pixel differences (SAD), both of which are computationally expensive operations. *See* Biswas1 at col. 5:45-54. The validation 122 accepts the first motion vector where the distortion is less than the selected limit error as selected motion vector. *See* Biswas at col. 5:65-67.

Biswas1's error threshold is a limit that specifies a maximum error allowed—not one that minimizes distortion as claimed. Specifically, at col. 5:62-65, Biswas1 states that "similarities between pixel values within the allowable selected limit for error provides an indication from the correlation 120 that a sub-block assignment for a candidate motion vector has been found." As a result, selecting a motion vector that is below the error threshold does not necessarily mean that this motion vector minimizes a distortion measure between the blocks of the predicted frame and a reference frame, with the distortion measure being MSE or SAD. Indeed, Biswas1 is silent on assigning a motion vector that minimizes a distortion measure.

An example may help clarify this point. Assume that there are 10 motion vectors under consideration for selection. As a result of Biswas1's error threshold (maximum error), Biswas1 will pick the very first motion vector that is below the error threshold, and stop processing any further motion vector. Assume that this was the first motion vector in the set of 10 motion vectors. Assume further that the tenth motion vector was the one that minimized distortion, as claimed. Biswas1's method would clearly not select this tenth vector. As should be logically apparent, the more motion vectors that Biswas1 tries to process, the more statistically unlikely it will be that the motion vector that he selects using the error threshold will be the one that minimizes distortion. Indeed Biswas1 specifically increases the number of motion vectors by using larger blocks when attempting to increase image quality. In other words, the more Biswas1 tries to increase image quality (by increasing the number of motion vectors he considers) the less likely statistically that he will select the motion vector that minimizes distortion, as claimed. Thus, Biswas1 does not ensure, and indeed makes increasingly unlikely, selecting the motion vector that minimizes distortion, as claimed.

In summary, there are a number of disadvantages of Biswas1 approach compared with the claimed method. First, Biswas1's correlation and validation process requires computationally expensive SAD or MSE calculation for a large number of candidate motion vectors due to lack of the claimed first two selection steps described above. Second, Biswas1 selects a motion vector out of the list of candidate motion vectors for any sub-block and the selected motion vector is merely good enough for image quality, but not necessarily the best (in terms of minimized distortion) motion vector for the block being encoded, as claimed.

The above two disadvantages inevitably lead to a third significant disadvantage: Biswas1 does not scale well to higher resolution images, such as Standard Definition and High Definition. For example, if small phase correlation blocks are used, such as 32x32 and 64x64 examples given by Biswas1, then only small motion vectors are produced. *See* Biswas1 at col.3:61. However, limiting candidate vectors will lead to poor compression efficiency at these high resolution images. On the other hand, if larger phase correlation blocks are used, such as 128x128 or 256x256, the potential number of phase correlation peaks could be in hundreds or even more, depending on the image content and/or noise, etc. In such case, Biswas1's correlation and validation technique becomes prohibitively computationally complex. To mitigate the complexity, Biswas1 loosens the error threshold to select a good enough candidate motion vector, which, in turn, will lead to poor compression efficiency, and again likely result in the select of a motion vector that does not minimize distortion.

Based on the above remarks, Applicants respectfully submit that for at least these reasons independent claims 1, 27, 28 and 53 are patentably distinguishable over the cited reference. Therefore, Applicants respectfully request that Examiner reconsider the rejection, and withdraw it.

The dependent claims are also patentable over Biswas1, both because each depends from patentable independent claims, respectively, and because each also recites its own patentable features. Therefore, Applicants respectfully submit that claims 1-16, 20, 22-55 and 57-58 are not anticipated by Biswas1.

Response to Rejection Under 35 USC § 103

Claims 6 and 33 are rejected under 35 U.S.C. 103(a) as being unpatentable over Biswas1 and in view of Zhang et al. (US 6,449,312). Claims 10-11 and 37-38 are rejected under 35 U.S.C. 103(a) as being unpatentable over Biswas1 in view of Aude. Claims 20, 21, 47-48, and 57-58 are rejected under USC §103 (a) as being unpatentable over Biswas1 in view of Biswas et al. "A Novel Motion Estimation Algorithm Using Phase Plane Correlation for Frame Rate Conversion" (Biswas2).

Response to Rejection under 35 USC § 103(a) over Biswas1 in view of Zhang

Zhang does not remedy the deficiencies of Biswas1. Zhang discloses a method of estimating motion in video using block matching metric. Zhang's estimation process searches a search window in a reference frame to try to find a match for an image block in a current frame.

First, Zhang's method of motion estimation is fundamentally different from the method disclosed by both the claimed invention and Biswas1. Zhang searches for the best motion vector candidate by starting at a certain point, and then moving along a search path according to various criteria. Thus, there is no inherent limitation in how far from the starting point the search path can continue. The decision to stop at a given point (i.e., search area) is based on the amount of time the search takes and the expected compression ratio. *See* Zhang at col. 3:20-40 and FIG. 1.

The claimed invention, however, uses the mathematical technique of phase correlation to measure the motion of objects and/or blocks in a frame, and dimensions M and N of the phase correlation blocks are each a power of 2 greater than 2S+16, where S is the maximum magnitude of the motion vectors in horizontal and vertical direction. In other words, only motion vector candidates whose magnitudes are restricted to the noted limits ("search area") can be considered. It should be clear then that the block size (dimensions M and N) is larger than the motion vector size.

Zhang's search window is not equivalent to the phase correlation block dimensions (M and N) as claimed. In Zhang, motion estimation in frame mode and field mode is conducted in a given search range, e.g., motion vector search window, and motion displacements (e.g., motion vector magnitude) can be as large as the search window. *See* Zhang at col.1:36-44 and col. 3:40-45. In contrast, in claim 6, the phase correlation block dimensions are specifically claimed as being more than twice as large as the motion vector search window. For example, assuming that the motion vector size used in both Zhang and the claim 6 is 128. Then Zhang would use a block size of 128x128, but the claimed invention would use a phase correlation block dimensions of 272x272 (i.e., 2S+16), instead of 128x128. This is beneficial for the operation of claim 1, but this modification of the Biswas1 would seriously impair the performance of Biswas1, since it would increase the size of his search area more than 450% (a search areas of 272x272 pixels is 4.51 times as large as a search area of 128x128 pixels). As noted above, increasing Biswas1's block size increases the number of motion vectors that he processes, resulting in decreased performance, and a statistical decrease in the overall image quality. See, MPEP 2143.01, Paragraph V, "If proposed modification would render the prior art invention being modified unsatisfactory for its intended purpose, then there is no suggestion or motivation to make the proposed modification. In re Gordon, 733 F.2d 900,

221 USPQ. 1125". The choice of M and N in this matter is beneficial in that it ensures that the phase correlation block is large enough to fully cover the entire search area for a macroblock of size 16x16 located at the center of the phase correlation block.

Thus, claims 6 and 33 are patentable over Biswas1 and Zhang, both individually and in combination. Other dependent claims recite similar language and are also patentable over Biswas1 and Zhang, both individually and in combination.

The claims not mentioned above depend from their respective base claims, which are patentable over Biswas1 and Zhang, both individually and in combination. In addition, these claims recite other features not included in their respective base claims. Thus, these claims are also patentable over Biswas1 and Zhang, both individually and in combination.

Response to Rejection under 35 USC § 103(a) over Biswas1 in view of Aude

Claims 10-11 and 37-38 are rejected under 35 USC §103 (a) as being unpatentable over Biswas1 in view of Aude. Aude teaches coherent and windowed sampling with A/D converters, which is sole reason Aude is cited by the Examiner. But Aude does not remedy the deficiencies of Biswas1 and Zhang as set forth above.

Thus, claims 10-11 and 37-38 are patentable over Biswas1 and Aude, both individually and in combination. Other dependent claims recite similar language and are also patentable over Biswas1 and Aude, both individually and in combination.

The claims not mentioned above depend from their respective base claims, which are patentable over Biswas1 and Aude, both individually and in combination. In addition, these claims recite other features not included in their respective base claims. Thus, these claims are also patentable over Biswas1 and Aude, both individually and in combination.

Response to Rejection under 35 USC § 103(a) over Biswas1 in view of Biswas2

Claims 20, 21, 47-48, and 57-58 are rejected under USC §103 (a) as being unpatentable over Biswas1 in view of Biswas2. Biwas2 does not remedy Biswas1, Zhang and Aude. Biswas2 teaches using phase plane correlation for frame rate conversion. Biswas2 uses a threshold value to evaluate the similarity between the current block of interest and its 8 neighbors. *See* Biswas2, Section 3. However, this threshold is unrelated to the number of the phase correlation peaks based on a maximum allowable motion vector magnitude. Further, because Biswas2 is merely a further elaboration of Biswas1 (that is, Biswas2 appears to include everything in Biswas1, plus additional content), the combination of these references provides nothing more than what Biswas2 alone discloses. As such, Biswas2 does not disclose the claimed features. Therefore, claims 20, 21, 47-48, and 57-58 are patentable over Biswas2 and other cited references, both individually and in combination.

In sum, all of the claims are patentable over all cited references, both individually and in combination.

Applicants note that narrowing amendments made in response to a previous Office Action has been reversed in this amendment. In view of the Federal Circuit's decision in *Hakim v. Cannon Avent Group PLC*, 81 U.S.P.Q.2d (BNA) 1900 (Fed. Cir. 2007), Applicants hereby rescind any disclaimer that may have resulted from the previous amendments or arguments associated therewith.

Conclusion

Applicants respectfully submit that the pending claims are allowable over the cited art of record for at least the above reasons and request that the Examiner allow this case. The Examiner is invited to contact the undersigned in order to advance the prosecution of this application.

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